MAR 22 2000

March 15, 2000

Joe and Sheila Keller
Joe Keller Trucking
183 Fairmont Road
Kalispell, MT 59901

Federal Caucus Comment Record
% BPA-PL
707 W. Main Street, Suite 500
Spokane, WA 99201

RE: Need to address forest health issues, that includes harvest more of trees to augment stream flows, especially late summer flows -- study attached.

To Whom It May Concern:

Breaching of the four lower Snake River dams is the most drastic, irrational and irreversible option for salmon recovery and will do little to restore salmon runs. It will not address over-harvest, predation by other endangered species, competition with non-native species, or most any of the other problems that face the fish. I believe the Caucus said there is 98% survival in fish transportation, but only about 5% return to spawn. What is happening to the fish from the time they get past the dams successfully -- that is what needs to be addressed.

Breaching dams will impact the entire economy of the region, especially agriculture, and is unnecessary with developing technology. There is already a prediciton of a power shortage this summer. The region is growing -- we can't stop that -- and computers with a great need for energy are going to increase exponentially.

1 **HABITAT:** We would specifically like to address habitat. The United States Forest Service from Washington, D.C., and locally, have documented a forest health problem. Foresters from Steve Mealy in Idaho to Region One Forester Dale Bosworth have said we have a forest health problem -- our forests are over-stocked with shade tolerant species, especially Douglas fir, that intercept and consume tremendous amounts of water before it reaches streams. When there are 600 mature trees per acre instead of 100 Ponderosa pine, and with this scenario repeated across the entire region, the impact on in-stream flows is very significant. Yet we are prevented at every turn from restoring our forests with common sense, science-based silvacultural methods that would help augment and create more natural stream flows.

The attached study on Waddel Creek in California concludes that it now takes more than 18 inches of rainfall to maintain the same instream flows that existed in the 1930's. The stream is

1 cont. becoming intermittent in late summer as the trees mature. There is no dam to augment flows for late summer fisheries survival.

Montana is endangering our own fisheries with the late summer augmentation from our own dams. It is late summer flows that are most needed for salmon recovery. The Swan River drainage in northwest Montana is one the strongholds of the bull trout, yet it is heavily managed by the Forest Service, Montana State Lands, Plum Creek and other private entities.

2 **FIRE:** Is fire the answer? September rains following the 1989 Tanner Gulch fire in the upper reaches of theGrande Ronde River, a prime salmon spawning stream, created a debris torrent that resulted in 100% fish kill for 36 miles downstream. According to Dr. Victor Kaczynski, a fisheries specialist who has worked on salmon recovery, listed the post-fire impacts on watersheds as increased spring runoff, decreased summer water volumes, increased erosion, decreased stream-side vegetation, increased summer water temperatures, decreased winter water temperatures, loss of spawning gravel and loss of soil nutrients. In September, 1994, Dr. Kaczynski said, "*No single forest practice - not timber harvesting, not road building - can compare with the damage wildfires are inflicting on fish and fish habitat. It is a paradox that the very fish we are trying to protect from extinction are now being threatened by fires many so-called environmentalists believe should be allowed to burn unchecked.*"

Even the 1910 Big Burn Fire in this northwest area, when humans were a very small factor since Montana, Idaho and eastern Washington were just beginning to be settled, greatly impacted fisheries. The fire burned through drainage after drainage across three million acres, crystalizing soils, boiling the water in streams, killing fish and sickening people after flowing through miles of ash.

COMMON SENSE: It is time for common sense to return to all government agencies that just seem to have gotten out of control when they embrace the most radical of every option devised.

Thank you for your consideration.

Joe and Sheila Keller

Sheila Keller Joe Keller

cc: Gov. Marc Racicot
Rep. Rick Hill
Sen. Conrad Burns
Sen. Max Baucus
Rep. Helen Chenoweth-Hage

RCN

good reason to thin, manage

Branching Out...

Ohio

Sponsored by the Union SWCD (USWCD), the Mullet County Forestry Field Day PLUS was held on Sunday, October 4, at the Keckley Rural Life Center on Bear Swamp Road in Union County from 12:00-4:00 p.m. Lunch consisted of chili, hot dogs and beverages, and was free of charge. Desserts were available for a slight charge.

Smokey Bear attended the field day to visit with all of his friends. Fun educational activities for children were scheduled for the wetland area. The ever-popular fishing activity for kids was available. Several exhibits were on display. Kathy Smith, RC&D Forester and John Rockenbaugh, Wildlife Specialist, joined forces to do forestry and nature walks.

All in all, the Forestry Field Day PLUS was a fun and educational activity for the family. For more information, contact Terri Gravatt, District Operations Coord., at the USWCD Office, 937/642-5871; fax -2825; e-mail uswcd@bright.net

The Fulton SWCD writes that the **Windbreak Spray Maintenance Program** is new for this fall. An application of weed control chemical will be applied on the windbreak in the fall. Cost for a windbreak of under 500 feet is 10¢ per row foot; from 500 to 1200 feet the cost is 9¢ per row foot; and for over 1200 feet the cost is 8¢ per row foot. Minimum charge is $50.00.

Several windbreak customers have volunteered their windbreaks to be used while the district tests to see which chemical applications are best. Contact the district at 419/337-9112.

California

Low stream flows are related to watershed reforestation, according to Santa Cruz County Resource Conservation District. Robert O. Briggs, Engineer/Researcher and Roberta K. Smith, Geologist have been studying Waddell Creek, a perennial coastal stream discharging into the ocean 20 miles north of the City of Santa Cruz; its watershed is 25 square miles. Dry season creek discharge has diminished significantly over the past half century—based on comparing continuous flow data recorded by Stanford Univ. and State Fish and Game researchers during the 1930s and 1940s with flow measurements made during the 1980s and 1990s. Mean dry season discharge (corrected for annual rainfall) during the 1980s is a fraction of its 1930s volume. No consequential diversion occurs above the measuring station, so natural causes must account for the reduced discharge.

Similar stream behavior in other studied watersheds has been attributed to competition for limited summer water by tree cover growth; this pattern fits Waddell Creek. The Waddell watershed was clear-cut and burned over before 1900. The tree cover had begun to recover by the 1930s and is now midway to full reforestation. Since a conifer uses approximately 90,000 pounds of water to create one pound of wood, regrowth of the redwood and Douglas-fir forest is a water intensive process that competes with streams for the limited summer water.

The Waddell forest biomass is increasing at about 3% per year and its water consumption during dry years is approaching the storage capacity of the aquifer. Waddell will probably become a seasonal stream sometime during the next century. A similar pattern has been noted on Scott's Creek, the watershed just south of Waddell, and may also be present on other streams in the area.

Editor's note: A similar situation occurred on the Quabbin Watershed in central Massachusetts. Intensive forest management, including low density harvesting practices, are being used to increase water quantity. Many of the old fields that naturally grew up to trees have been clearcut and returned to their open-pasture status. These fields are maintained so as to not allow trees to establish.

For more information on the Waddell Creek study and a recap of the scientific literature cited in the study, write the Santa Cruz County RCD, 5161 Soquel Drive, Ste. F, Soquel, CA 95073, or fax 408/475-3215.

Maine

The forest product industry in the Pine Tree state will soon face more **public discussion on harvest practices.** The Maine Forest Service has developed a set of proposed changes to the state's Forest Practices Act. After a series of late summer public hearings, the forest service will prepare a final package to be presented to the state legislature in January 1999.

As currently proposed, the rule changes would require increased buffer areas around clearcuts with a minimum of 60 square feet residual basal area in the buffers. These clearcuts would also be limited to 75 acres, down from the current 250-acre limit. The proposals would, however, show clearcuts larger than 75 acres when state issued permits are granted on the basis of significant biological and silvicultural justification. Shelterwood harvests would also be significantly regulated under the new proposals, raising doubts by some woodlands managers about their ability to utilize this valuable harvesting treatment.

Incorporated in these proposals are additional changes, directed by recent legislative action, that require on-site posting of harvest information in an effort to discourage timber theft. Such notices must list the names of landowners or their agents, foresters and harvesters, and must be maintained conspicuously at or near the harvest sites during and for a least 60 days following completion of the harvests. The proposed rules also list additional reporting requirements associated with clearcuts, including locations, sizes and reasons for clearcutting.

The public debate about forest practices is expected to continue well into 1999 as the Forest Service and state legislature work to develop and enact this new policy. Meanwhile, rumblings from some environmental groups continue to make reference to another referendum focused on clearcuts and herbicide use, but industry critics have not yet taken formal steps to begin a petition drive to place a referendum on the ballot. Sources: The Northeastern Loggers' Assn. of Olde Forge, NY and the Maine Forest Products Council. For specifics contact the Maine Forest Service at 207/287-2793; fax -8422.

Minnesota

The Onanegozie RC&D is involved in a **green hardwood dimension project.** Green Hardwood Dimension is a process where lower quality hardwood logs are sawn and the defects immediately removed. The high grade parts are then kiln dried at the rural sawmill before shipping to the secondary manufacturer. Green Dimension will eliminate unnecessary trucking, reduce kiln drying of wood products that are considered waste, create economic diversity with more jobs in rural settings, and provide more forest management options. This project is a multi-state cooperative effort to demonstrate Green Hardwood Dimension at Palisade Supply, a rural MN sawmill. Eventually, more than 11 state, regional, and federal agencies invested more than $250,000 to assist completion of this project. Three demonstration workshops, involving more than 300 participants, have been held in WI, IN, and MN. A low-cost consultant service was organized and funded for those participants who wanted to learn more about how Green Dimensions would work at their operations. Contact: Onanegozie RC&D at 320/679-4604.

Oklahoma

James Hopson, owner of Larue's BBQ four miles north of Warner on Hwy. 64, has a **dry hydrant** on his pond near his restaurant, according to the Muskogee County Conservation District. The hydrant, installed in April '98, is the result of cooperation among several agencies. The Oklahoma Dept. of Agriculture, Forestry Division, has a Rural Fire Defense program that provides the materials for the hydrants. The intent of the program is to have an available and dependable source of water to fight fires within

Hard to believe

1 lb. of wood is how much % of annual growth?? – 10% – 50% – 250% ???
Estimate DF – 35# / cubic foot. [illegible] 100 cubic ft / year × 35 = 3500 # then 3500 × 90,000 = 31,500,000
Cottonwood – 28 # / cubic foot.
315,000 ÷ 8.3 = 37,9[illegible]

COMPETITION FOR LIMITED DRY SEASON GROUND-STORED WATER BETWEEN FOREST USE AND STREAM FLOW IN THE WADDELL VALLEY

By

Robert O. Briggs

Presented, October 9, 1997 - Davenport Geological Society

ABSTRACT

Waddell Creek summer discharge -which in the short term is proportional to the previous season's total precipitation - has diminished over the past six decades for a given annual rainfall. There is no significant diversion above the gauging stations so a natural cause for the long-term summer flow decline has been considered. As demonstrated in other watersheds, water consumption by the growing plant colonies in the Waddell Valley appears to have reduced dry season stream discharge.

The Waddell watershed was deforested at the turn of the last century and since then the redwood and fir have partially recolonized, resulting in a long-term increase in forest water uptake and consequent reduction of dry season water available to supply the creek. Baring interruptions of the reforestation process or some other limitation, the forest's dry season water uptake will continue to increase as the forest continues to mature, gradually approaching a condition wherein further growth is limited by reduced dry season water supply. As a result, Waddell Creek late summer flow can be expected to continue diminishing and to become intermittent with increasing frequency over the next few decades.

The incompatibility between unrestricted forest growth and bountiful late summer stream flow could be significant in environmental planning.

Revised, November 15, 1998

COMPETITION FOR LIMITED DRY SEASON GROUND-STORED WATER BETWEEN FOREST USE AND STREAM FLOW IN THE WADDELL VALLEY

Introduction

Waddell Creek is a perennial, central California, coastal stream. It drains a forested 25 square mile watershed to the Pacific Ocean about 20 miles north of the city of Santa Cruz. The map, Figure 1 shows the location of Waddell Creek.

The precipitation pattern on the central California coast consists of a half-year wet season from about mid October to April or May, followed by a half-year dry season. Water is stored in the ground during the rainy season but during the dry season that stored water is the only water available to both the creek and the forest. This supply feeds the summer creek from numerous springs and also is the water source for the forest during the peak redwood-growing season from May through August.

This study examines the long-term dry season behavior of Waddell Creek, demonstrates the effect of reforestation on its flow pattern over the past six decades and estimates the magnitude of the ongoing decrease in its summertime discharge as functions of time and rainfall.

History of the Waddell Watershed and Forest

Prior to European settlement, the Waddell watershed was forested with redwoods, Douglas fir and a scattering of hardwoods such as tan oak and madrone. Local natives periodically set fires to clear the forests and enhance game hunting opportunities and natural fires were frequent. These fires had minor impact on large trees, kept small trees and underbrush at a minimum and deforested marginal growing areas. (Bonnicksen, 1997)

The first major impact by European settlers on the Waddell Valley was the timber harvest activities of William Waddell from 1862 to 1875. Contemporaneous reports and physical archeological evidence indicate that Waddell cut a majority of the merchantable trees in the valley (perhaps 90% of the total biomass) and further impacted the watershed by burning the waste and slash in situ. He left only a few large, isolated redwood trees, some stands of smaller, unmerchantable trees and a few small groves of larger trees in steep, inaccessible canyons. In early September of 1904, following Waddell's harvest, a major fire destroyed many of the remaining smaller and emerging trees in the watershed. A contemporaneous local newspaper "Santa Cruz Daily Surf" reported that this fire engulfed the coastal slope of the mountain range from Pescadero to Santa Cruz. Following that event, a smaller fire burned the lower Waddell Valley in August of 1910. Since then, for most of this century, logging in the Waddell Basin has been curtailed or practiced on a selective harvest "tree farming" basis with continued regrowth encouraged, and forest fires have been artificially controlled. The result has been a steady regrowth of the forest throughout the watershed. Professional foresters report that the total forest area in the Waddell Basin is greater than during the pre-Waddell era and estimate that the timber biomass growth rate in this watershed is currently on the order of 3%/year.

The growth rate of the biomass in this forest may be beginning to decline but is not approaching the plateau of a mature forest. Unless interrupted, it will continue to increase for many years until it approaches some limiting constraint (Holderman, 1985). Figure 2 compares tree cover of Waddell valley hillsides as they appeared in the early 30s with a recent view to illustrate changes in forest cover of the watershed.

Discharge Patterns of Waddell Creek

Waddell Creek discharge varies over a huge range: 1) from winter to summer, 2) from year to year as rainfall varies and 3) from decade to decade in a long-term decline. Following a January 3, 1982 rain storm which delivered 10 inches in 24 hours in the lower valley and probably more at higher elevations, Waddell discharge was estimated by Robert O. Briggs[1] at 11,000 cubic feet per second (cfs). By contrast, on August 20, 1977, following two years of drought, the flow was measured (using a Parshall flume) at 0.17 cfs, a dynamic range of 64,000,000:1.

During the half-year wet season from early autumn till mid spring, the mean rainfall at the lower elevations of the watershed is currently 31.9 inches and about 1.5 times that amount at the higher elevations (Rischbieter and

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[1] The discharge was estimated by clocking the speed of debris movement and multiplying the estimated speed by the cross section area of the channel.

Waldron, 1998). During the 44 years for which continuous local rainfall records are available (Frank McCrary, 1998) the annual total has varied from 13.26 inches in the 1975-76 season to 50.02 inches in 1994-95.

Rain runoff produces heavy, transient winter discharge. Summertime flow, however, is almost totally spring-fed by ground storage from the winter rains. During the six-month dry season, the water table drops and stream flow decreases proportionately. From the time of the last rains of the season till the onset of the following rainy season, the summer recession pattern empirically approximates the first order exponential function:

$$Q_2 = Q_1 e^{-(\Delta t)/T} \qquad \text{(Equation 1)}$$

where: Q_1 = discharge at time 1
Q_2 = discharge at time 2
Δt = elapsed time between Q_2 and Q_1
T = time constant of the system (time required for the dependent variable to reach 1/e of an original value)
e = base of the natural log

The fidelity of the summer discharge patterns to the exponential recession model is apparent in figure 3 since the data approximate the straight line of an exponential function plotted in semi-log space.

Theodore Hoover's Observations

Anecdotal and engineering descriptions of Waddell Creek in the first half of this century tell of a bountiful late summer flow, even in the driest years. Theodore Hoover, a noted geologist who studied the valley in 1898, acquired most of the lower part of the watershed in 1913. His 1939 autobiography quotes from his 1913 diary notation (Hoover, 1939):

"It has a stream with a minimum September flow of 1800 gallons per minute flowing through its long axis."

In 1939, Hoover, having lived on the property for most of two decades, wrote:

"The flow of Waddell Creek at the lowest water and driest year ever known is a minimum of 1200 gallons per minute" (Hoover, 1939)

By contrast, in 1977, with a season total of 16.23 inches of precipitation, the minimum flow was 0.17 cfs (76.5 gallons per minute) and that was the lowest discharge ever recorded (Briggs, 1991, Briggs, 1994). It was probably lower in 1976, the year of the lowest rainfall on record, (13.26 inches) but no discharge data are available for that year.

The disparity between the earlier reports of bountiful summer flow and recent much lower measurements suggested that something in the Waddell hydrologic system has changed or is changing. Other information contributes to and clarifies this observation.

Shapovalov and Taft Discharge Data, 1933 to 1942

When continuous, nine year engineering flow measurements were made during the 1930s, (Shapovalov and Taft, 1954) the mean late summer discharge was higher than in all but the wettest 5th percentile of the past 10 years. Table 1 presents the average monthly discharge of Waddell Creek for each summer month of the 9 years of the 1930s study. The values were taken from a graphic presentation in the Shapovalov and Taft (1954) report and their precision is limited to no more than two significant figures by the small size and nonlinear scale of the graphs. The calculated average of the nine discharge values for each month is representative of mean monthly discharge for this period.

TABLE I
WADDELL CREEK, 1934 -1942
AVERAGE SUMMER MONTHLY DISCHARGE
(Shapovalov and Taft, 1954)

Year	APRIL	MAY	JUNE	JULY	AUG.	SEPT.
1934[2]	5 cfs	3.5	2.5	1	0.9	0.8
1935	25	20	14	7.5	4.5	2
1936	30	25	15	7.5	5	5
1937	35	20	15	7.5	5	4.5
1938	50	23	6	6	4.5	4
1939	10	10	5	4.5	4.5	4
1940	75	27	20	10	4.5	4
1941	125	30	20	10	4.5	4
1942	70	40	25	20	16	6
9 year average	42.	22	14	6.7	4.5	3.1

Recent Discharge Data

Since the study covering 1932 to 1941 (Shapovalov and Taft, 1954), Waddell Creek has not had a continuous discharge-recording program and, until 1988, only occasional measurements were recorded. Due to the lack of better information, important decisions concerning water usage, fish habitat etc. have been based on the 1930's Shapovalov and Taft information which we now know is not valid for present conditions.

In 1987, the California State Coastal Conservancy contracted with hydrology consultant Robert Coats of Phillip Williams and Associates to study Waddell Creek in conjunction with the Conservancy's interest in diverting Waddell water for agricultural applications to a nearby watershed. Correlating the fragmentary Waddell data with continuous U. S. Geological Survey records for nearby Pescadero Creek, Coats constructed a model of Waddell flow in the form of monthly flow duration charts (Coats, 1988). A comparison of Coats' 50th percentile figures with mean monthly summer flow (Shapovalov and Taft, 1954) suggested a significant reduction in discharge over the intervening half-century.

The implications of this observation led the author to begin recording summer Waddell discharge by open stream survey in 1988 and continuing the measurements to the present. With ten years of recent data to compare with the 9 years of 1930's data, the observation of reduced summer discharge is unequivocally demonstrated. Figure 3 compares the mean summer monthly discharge during the 1934-42 period with the mean monthly discharge from 1988 to 1997. The deviation of the data from the exponential line in early fall probably shows the reduced water demands of the trees in the watershed and riparian zone as they become less active toward the end of the growing season.

Figure 4, displaying the summer discharge pattern for 1995, is especially interesting. Precipitation for that rainfall year was 50.02 inches and the discharge throughout the summer is nearly identical to that of the earlier 9-year mean flow pattern with an average rainfall of 31.9 inches. This suggests that the difference in creek flow for the two periods is equivalent to 18 inches of rainfall. That is, in 1994-95 it took 50 inches of rainfall to produce the same summertime stream discharge caused by 31.9 inches during the 1930's. This impact is on the high end of the

[2] The temporary dam used for these flow measurements was built in 1932-33. During the first year of its service there appears to have been substantial leakage around and under the dam so the 1934 flow data are understated. Over time the leakage was caulked by creek siltation and subsequent measurements are consistent and believed accurate.

range of depletion reported in other locations for different types of forest. Information on redwood forest for direct comparison to Waddell Valley is not available but the figure is similar to that reported for the Oregon Cascades (Dunn and Leopold, 1978). The Cascades are forested predominantly in douglas fir with some western pine and other species (Cobb and Dobell, et al 1961). The early growth pattern of these trees is similar to that of Redwoods but firs reach maturity and consequently a condition of stable water uptake earlier in their lives than do redwoods.

Competition Between Trees and Streams

The explanation for the summer flow depletion that seems to fit the Waddell Valley observations is that of increased summer water use by the growing forest. Trees remove remarkably large amounts of water from the soil, and during the dry season this water is not available to supply the stream (DeCoster and Herrington, 1988). The following is a quote from the DeCoster and Herrington report.

"A medium sized tree (40-50 feet tall) will take 10,000 gallons (83,000 pounds) of water from the soil in a growing season."

The report further states:

"A tree uses 55 pounds of water to make 100 pounds of cellulose, the main constituent of wood, but it evaporates more than 90,000 pounds of water in the process."

This report also cites a study done by the Baltimore City Watershed wherein young pine trees were planted on a bare watershed and the annual surface water yield was reduced by 283,000 gallons per acre per year, (which is equivalent to 13.3 inches of perception per year).

Dunn and Leopold (1978) also discuss the competition between trees and streams in the book Water in Environmental Planning This source states:

"Over hundreds of square kilometers of the eastern United States, farm abandonment and re-colonization of the land by pines, spruce, or cedar have been occurring throughout this century. There is reason to believe that this vegetation change has reduced streamflow by important amounts, and that it will continue to do so at a time when water supplies for some eastern cities are becoming critically short. Re-growth of conifers on the 1027 km^2 Sacandaga River catchment in the Adirondack Mountains, for example, caused increases in interception and evapotransiration losses. The increase in the loss of water has risen to over 200,000,000 cubic meters per year by 1950, This amount of water is large enough to supply more than one million people."

This is equivalent to 7.4 inches of rainwater per year.

(Larcher, 1975) shows the amounts of water and the percentage of the total annual precipitation consumed by colonies of various plants in numerous worldwide geographic locations. Trees of a wide variety and under a broad range of growing conditions are shown to use from 43% to 160% of incident annual precipitation.

Although healthy forests are part of a balanced ecology, it must be realized by environmental planners and others that trees compete with streams for a limited summer supply of stored water since water consumed by trees is not available to streams. Ecologists report that anadromous fish habitat improves almost linearly with stream flow up to the level limited by overflow of the stream banks (Snyder et al., 1995).

Dunn and Leopold (1978) examined the quantitative effect of forest growth on watershed performance, providing a mathematical basis for prediction of flow depletion as the forest grows. These investigators analyzed several studies and conclude the following:

"The data indicate that increases in stream flow caused by deforestation decline exponentially with time."

This is expressed by an exponential relationship: (Dunn and Leopold, 1978)

$$Q_2 = Q_1 (1-r)^N \qquad \text{(Equation 2)}$$

Where:
Q_1 = discharge at time 1
Q_2 = discharge at time 2
N = time (years) between Q_2 and Q_1
r = annual rate of decrease

Solving equation 2 for r:

$$r = 1 - (Q_2/Q_1)^{1/N} \qquad \text{(Equation 3)}$$

To find the annual rate of discharge decrease for the month of September for normal rainfall we can take a numerical example using values from figure 5, for each time period at 30 inches of rainfall

Q_1 = 4.25 cfs
Q_2 = 1.5 cfs
N = 55 years

And solving for r yields a decline rate of 1.9% / year.

Since dry season discharge is proportional to rainfall, this rate of reduction should apply in comparing September flow for the two periods separated in time but with the same rainfall.[3]

Correlation of summer discharge with rainfall

Waddell Creek summer discharge correlates well with the total rainfall of the preceding season; however, there is very little correlation with the distribution of rain throughout the season or with the previous year's rainfall.[4] Figure 5 plots mean discharge for the month September for each year showing the year as a single point of discharge vs. rainfall. The difference in flow between the two periods for a given rainfall is apparent.

Prediction of summer flow as a function of annual rainfall

Equation 2 tells that if discharge (Q_1) for a given date of a year with known rainfall is compared with the discharge (Q_2) on the same date of a later year with identical rainfall, the Waddell Creek summer discharge can be predicted by using the r value of 1.9 % per year flow decrease from equation 3 for any given rainfall and any nearby future year. As the forest matures the value of r will asymptotically approach zero but the time scale of that recession is indeterminate with presently available information.

Prediction of intermittent flow probability

The lowest flow ever recorded in Waddell Creek, 0.17 cfs, occurred in August of 1977 with precipitation of 16 inches (Briggs, 1989). Observation of 1977 creek behavior, as the flow diminished, disclosed that a discharge of less than 0.2 cfs causes intermittent flow at various stations along the creek. Thus, for the purpose of predicting creek intermittence, a discharge of 0.2 cfs is the critical threshold.

Extending the best-fit line for recent September discharge to intersect the 0.2 cfs level in figure 5 suggests that, with present forest cover and a rainfall of less than 15 inches, intermittence may be expected.

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[3] Applying equation 3 to the casual minimum flow remarks of Theodore Hoover (1939), 1800 gpm and 1200 gpm and the time span from 1913 to 1931, a depletion rate (r) of 2.01% per year is found for that period.

[4] Luna B. Leopold (1995) suggested testing the correlation of summer flow with precipitation of the last three months of the rainy season. However, no significant correlation with that or other functions of rainfall distribution or cumulative previous yearly rainfall was discovered.

A rainfall exceedence probability analysis derived from the past 44 years of local rainfall records (McCrary, 1998) shows the probability of 15 inch or lower annual precipitation to be about 5%. Thus, for the present intermittence threshold of 15 inches, the probability of stream failure in the month of September is approximately 5%. The flow can be expected to fail more frequently and for longer periods of time over the next few decades.

CONCLUSION

Waddell Creek late summer discharge has significantly fallen over the past half century due to reforestation of the watershed. Following a very weak rainy season, the creek flow ceases toward late summer and the rainfall threshold of this effect will advance with time as the forest continues to grow and expand. If the forest biomass increase continues with no limiting events such as major fires or timber harvest, Waddell Creek will ultimately become seasonal. Therefore, it is of great importance that policy makers recognize the competition in some watersheds between forests and streams for limited available dry season water reserve and realize that maximizing forest growth and maintaining or increasing stream flow may be incompatible goals.

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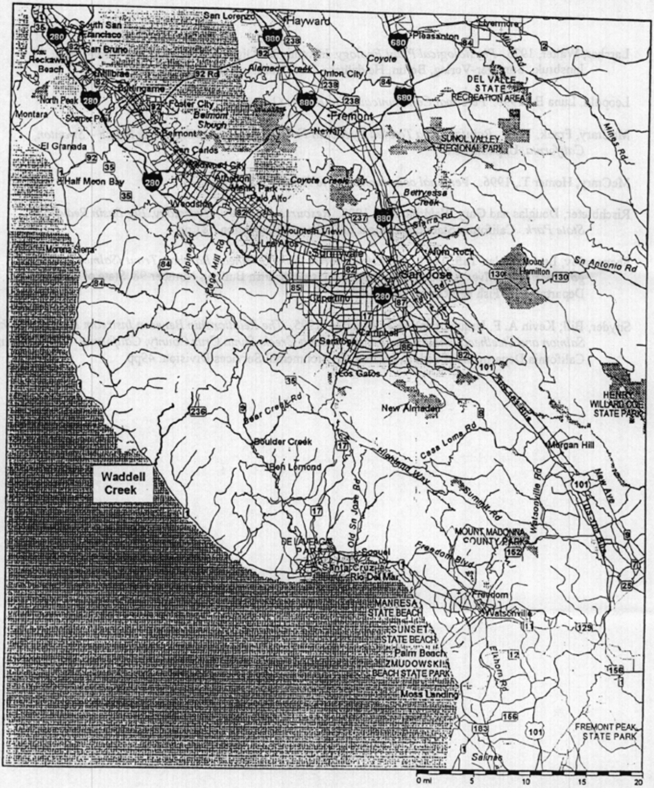

Figure 1. California coast from Half Moon Bay to Moss Landing showing the location of Waddell Creek.

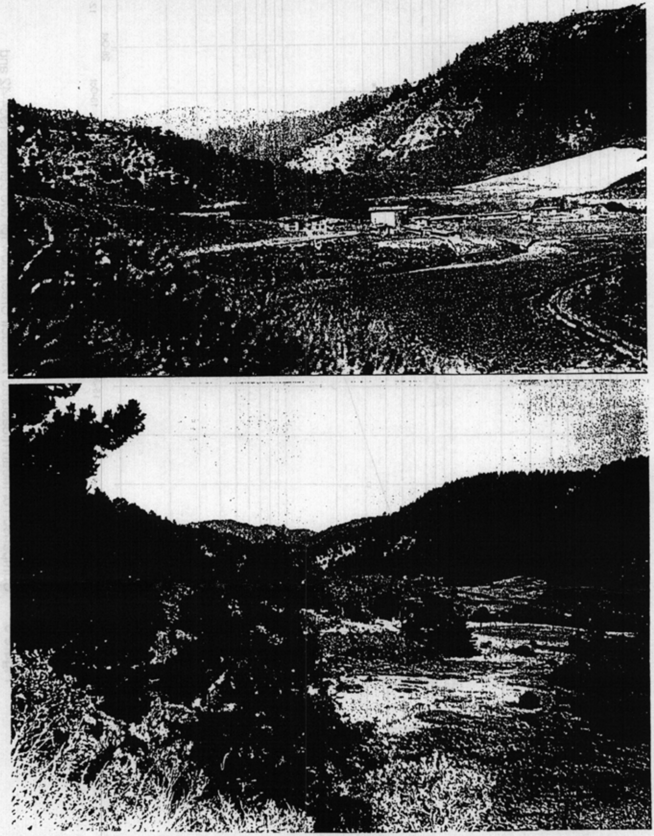

Figure 2 Looking northward from a point above the west gate of Rancho del Oso showing the increase in forest density of the watershed between 1930 and 1991.

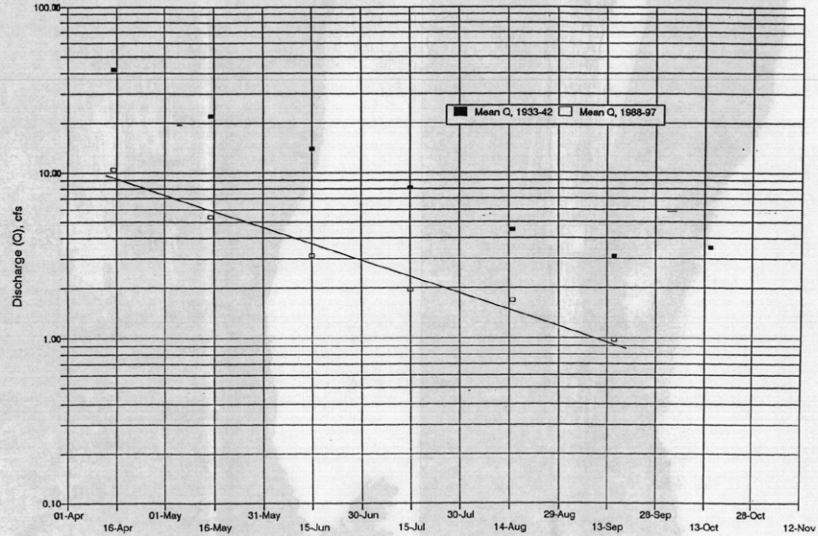

Figure 3 Comparison of mean measured Waddell Creek flow for two periods, 1934-42 and 1988-97 demonstrating summertime flow reduction over that time span.

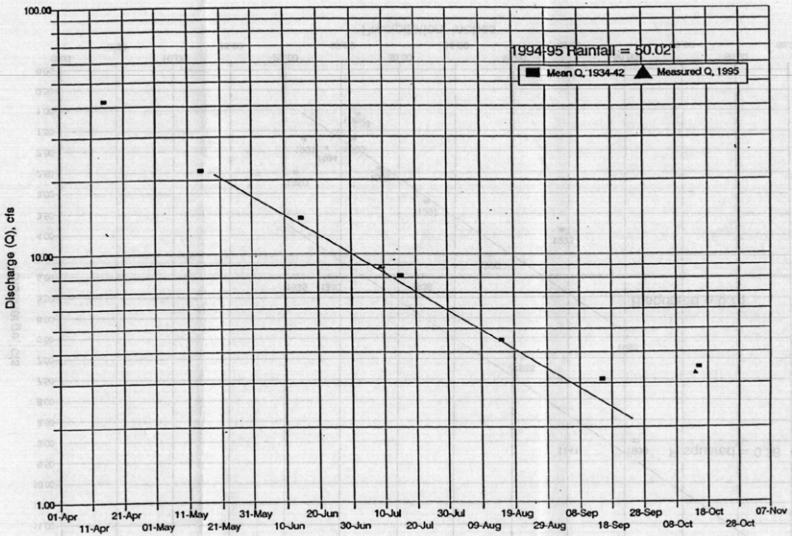

Figure 4 Mean summer monthly discharge during 1934-42, a period with an average rainfall of 31.9 inches, compared with the measured monthly flow of the 1995 summer with 50 inches of precipitation. This suggests that the drop in summer discharge is equivalent to 18 inches of rain.

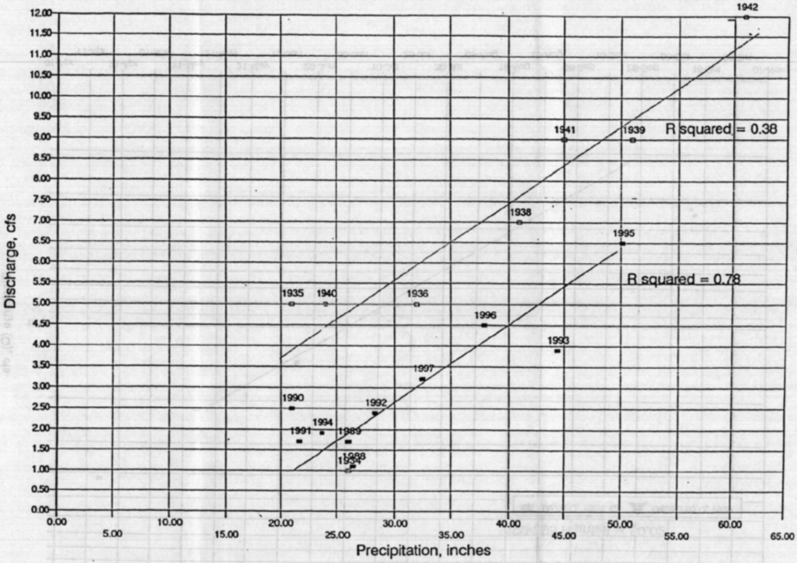

Figure 5 Waddell Creek mean September discharge vs. rainfall for each year of the two periods, 1934-42 and 1988-97.